

We claim:

- 1 1. A method of fabricating an encapsulated metal structure in
2 a feature formed in a substrate having a top surface, the
3 feature having sidewalls and a bottom, at least the sidewalls
4 and bottom being covered by a first barrier layer and the
5 feature being filled with metal, the method comprising the
6 steps of:
7 forming a recess in the metal, so that a top surface of
8 the metal is lower than the top surface of the substrate;
9 depositing an additional barrier layer covering the top
10 surface of the metal and contacting the first barrier layer;
11 and
12 planarizing the additional barrier layer.
- 1 2. A method of fabricating an encapsulated metal structure
2 according to claim 1, wherein the method is repeated so that,
3 after a final barrier layer is planarized, the top surface of
4 the substrate is exposed and the metal is encapsulated by the
5 first barrier layer and at least one additional barrier layer
6 including the final barrier layer.
- 1 3. A method of fabricating an encapsulated metal structure
2 according to claim 1, wherein said step of forming a recess in
3 the metal and said planarizing step are performed by chemical-
4 mechanical polishing (CMP).

1 4. A method of fabricating an encapsulated metal structure in
2 a feature formed in a substrate having a top surface, the
3 feature having sidewalls and a bottom, the method comprising
4 the steps of:
5 depositing a first barrier layer on the top surface of the
6 substrate and on the sidewalls and bottom of the feature;
7 filling the feature with metal;
8 forming a recess in the metal, so that a top surface of
9 the metal is lower than the top surface of the substrate;
10 depositing a second barrier layer on the top surface of
11 the metal; and
12 planarizing the first barrier layer and the second barrier
13 layer so that the top surface of the substrate is exposed and
14 the metal is encapsulated by the first barrier layer and the
15 second barrier layer.

1 5. A method of fabricating an encapsulated metal structure
2 according to claim 4, wherein said step of filling the feature
3 with metal further comprises:
4 depositing a seed layer of the metal on the first barrier
5 layer; and
6 electroplating the metal using the seed layer.

1 6. A method of fabricating an encapsulated metal structure
2 according to claim 4, wherein said step of forming a recess in
3 the metal and said planarizing step are performed by chemical-
4 mechanical polishing (CMP).

1 7. A method of fabricating an encapsulated metal structure
2 according to claim 5, wherein the metal is electroplated on the
3 top surface, and said step of forming a recess in the metal
4 further comprises removing the metal from the top surface.

1 8. A method of fabricating an encapsulated metal structure in
2 a feature formed in a substrate having a top surface, the
3 feature having sidewalls and a bottom, the method comprising
4 the steps of:

5 depositing a first barrier layer on the top surface of the
6 substrate and on the sidewalls and bottom of the feature;
7 filling the feature with metal;

8 forming a first recess in the metal, so that a top surface
9 of the metal is lower than the top surface of the substrate;

10 depositing a second barrier layer on the top surface of
11 the metal; and

12 planarizing the first barrier layer and the second barrier
13 layer so that the top surface of the substrate is exposed, a
14 remaining portion of the second barrier layer is on the top
15 surface of the metal and a portion of the top surface of the
16 metal is exposed;

17 forming a second recess in the metal at the exposed
18 portion thereof;

19 depositing a third barrier layer on the top surface of the
20 metal and on the remaining portion of the second barrier layer,
21 thereby filling the second recess in the metal; and

22 planarizing the third barrier layer so that the top
23 surface of the substrate is exposed and the metal is
24 encapsulated by the first barrier layer, the second barrier
25 layer and the third barrier layer.

1 9. A method of fabricating an encapsulated metal structure
2 according to claim 8, wherein said step of filling the feature
3 with metal further comprises:

4 depositing a seed layer of the metal on the first barrier
5 layer; and

6 electroplating the metal using the seed layer.

1 10. A method of fabricating an encapsulated metal structure
2 according to claim 8, wherein said step of forming a first
3 recess in the metal, said step of forming a second recess in
4 the metal and said planarizing steps are performed by chemical-
5 mechanical polishing (CMP).

1 11. A method of fabricating an encapsulated metal structure
2 according to claim 9, wherein the metal is electroplated on the
3 top surface, and said step of forming a first recess in the
4 metal further comprises removing the metal from the top surface.

1 12. A method of fabricating a metal-insulator-metal (MIM)
2 capacitor, the method comprising the steps of:
3 providing a first substrate layer with a feature formed
4 therein, the first substrate layer having a top surface, the
5 feature having sidewalls and a bottom;
6 forming an encapsulated metal structure in the feature,
7 where the sidewalls and bottom of the feature are covered by a
8 first barrier layer and the feature is filled with metal
9 covered by an additional barrier layer in contact with the
10 first barrier layer;
11 depositing a second substrate layer on the top surface of
12 the first substrate layer and overlying the encapsulated metal
13 structure;
14 forming an opening in the second substrate layer to expose
15 the encapsulated metal structure;
16 depositing a dielectric layer on the second substrate
17 layer, covering sidewalls of the opening and the exposed
18 encapsulated metal structure at a bottom of the opening;
19 depositing an additional layer to cover the dielectric
20 layer on the sidewalls and on the bottom of the opening and to
21 fill the opening; and
22 planarizing the dielectric layer and the additional layer.

1 13. A method of fabricating a MIM capacitor according to claim
2 12, wherein said step of forming an encapsulated metal
3 structure comprises:

4 depositing the first barrier layer on the top surface of
5 the substrate and on the sidewalls and bottom of the feature;
6 filling the feature with metal;

7 forming a recess in the metal, so that a top surface of
8 the metal is lower than the top surface of the substrate;

9 depositing the additional barrier layer to cover the top
10 surface of the metal and contact the first barrier layer; and
11 planarizing the additional barrier layer.

1 14. A method of fabricating a MIM capacitor according to claim
2 13, wherein the steps of forming a recess in the metal,
3 depositing the additional barrier layer and planarizing the
4 additional barrier layer are repeated so that, after a final
5 barrier layer is planarized, the top surface of the substrate
6 is exposed and the metal is encapsulated by the first barrier
7 layer and at least one additional barrier layer including the
8 final barrier layer.

1 15. A method of fabricating a MIM capacitor according to claim
2 13, wherein the steps of forming a recess in the metal and said
3 planarizing steps are performed by chemical-mechanical
4 polishing (CMP).

1 16. A method of fabricating a MIM capacitor according to claim
2 12, wherein said step of planarizing the dielectric layer and
3 the additional layer removes the dielectric layer and the
4 additional layer from a top surface of the second substrate
5 layer, so that the top surface of the second substrate layer is
6 exposed, and a remaining portion of the dielectric layer and a
7 remaining portion of the additional layer are disposed in the
8 opening.

1 17. An encapsulated metal structure formed in a feature of a
2 substrate, the substrate having a top surface, the feature
3 having sidewalls and a bottom, the structure comprising:

4 a first barrier layer covering the sidewalls and bottom of
5 the feature;

6 metal filling the feature and having a recess formed
7 therein, so that a top surface of the metal is lower than the
8 top surface of the substrate; and

9 an additional barrier layer covering the top surface of
10 the metal and contacting the first barrier layer so as to
11 encapsulate the metal, the additional barrier layer being
12 planarized so that the top surface of the substrate is exposed.

1 18. An encapsulated metal structure according to claim 17,
2 wherein the metal comprises copper.

1 19. An encapsulated metal structure according to claim 17,
2 wherein the first barrier layer comprises tantalum and tantalum
3 nitride.

1 20. An encapsulated metal structure according to claim 17,
2 wherein the additional barrier layer has a top surface planar
3 with the top surface of the substrate.

1 21. A metal-insulator-metal (MIM) capacitor structure,
2 comprising:

3 a first substrate layer with a feature formed therein, the
4 first substrate layer having a top surface, the feature having
5 sidewalls and a bottom;

6 an encapsulated metal structure in the feature, where the
7 sidewalls and bottom of the feature are covered by a first
8 barrier layer and the feature is filled with metal covered by
9 an additional barrier layer in contact with the first barrier
10 layer, to form a lower plate of the capacitor structure;

11 a second substrate layer on the top surface of the first
12 substrate layer, the second substrate layer having an opening
13 formed therein overlying the encapsulated metal structure;
14 a dielectric layer covering sidewalls of the opening and a
15 portion of the encapsulated metal structure at a bottom of the
16 opening; and
17 an additional layer covering the dielectric layer on the
18 sidewalls and on the bottom of the opening and filling the
19 opening, to form an upper plate of the capacitor structure,
20 wherein the dielectric layer and the additional layer are
21 planarized so that the top surface of the second substrate
22 layer is exposed.

1 22. A MIM capacitor structure according to claim 21, wherein
2 the metal comprises copper.

1 23. A MIM capacitor structure according to claim 21, wherein
2 the first barrier layer comprises tantalum and tantalum
3 nitride.

1 24. A MIM capacitor structure according to claim 21, wherein
2 the dielectric layer comprises Ta_2O_5 .

1 25. A MIM capacitor structure according to claim 21, wherein
2 the additional layer comprises tantalum nitride.